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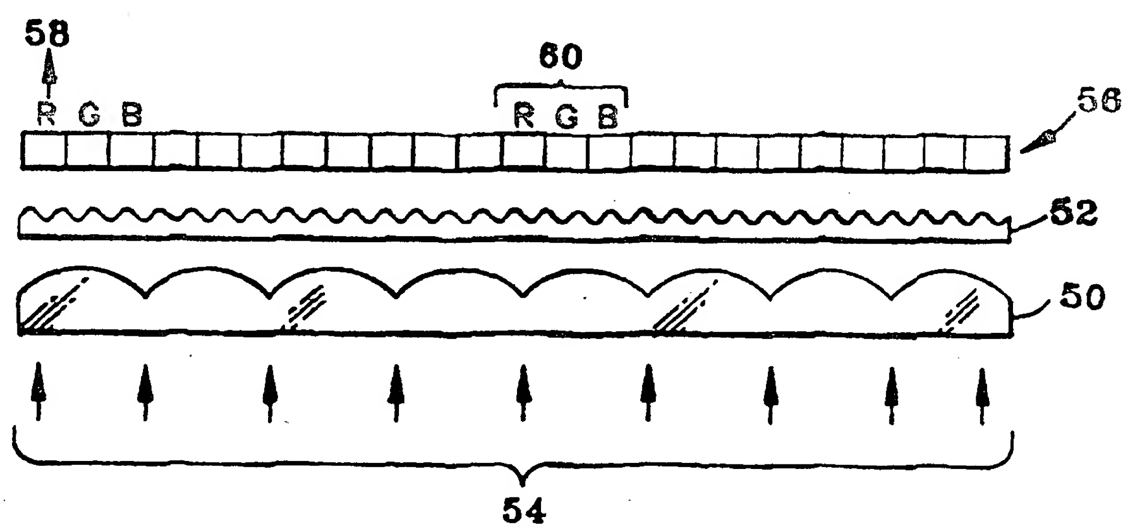

(57) Abstract

Optical apparatus for dispensing a visible light spectrum into primary color bands and directing each color band into a specific pixelated cell of a passive display. The apparatus includes an array of refractive microlenses arranged parallel to the plane of the passive display such as a liquid crystal display and a diffraction grating arranged parallel and in close proximity to the lens array. The microlenses focus visible light onto the display while the diffraction grating separates the visible light into primary color bands in different diffraction orders such that the colors are directed to and transmitted through the corresponding specific pixelated cells.

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DIFFRACTIVE MICROSTRUCTURES FOR COLOR SEPARATION AND FUSING

Background of the Invention

This invention relates to an optical apparatus and a method for separating visible light into its primary colors and directing each color into a corresponding pixelated cell of a passive display.

Today, there is a growing demand for more energy efficient color display devices for applications such as small portable televisions and notebook computers. The traditional cathode ray tube technology is unsuitable for these display device applications as these applications have restrictions in size, weight and energy efficiency, yet still require bright display of colors. To accommodate these restrictions, research and development efforts have been focused on passive display devices such as liquid crystal displays. In liquid crystal color displays, back illumination is frequently used as the light source; therefore, an important step in improving the liquid crystal display technology is to find a way to efficiently separate and image the back light into bright colors.

There are two common methods for achieving color images. One method uses a small filter of a particular color placed in front of each liquid crystal cell such that only light corresponding to one of the three primary colors is transmitted. Thus, each pixel contains three cells that each transmits red, green or blue. This method is inefficient because two thirds of the source light is lost in passing through each filter. The other method for color imaging employs dichroic beam splitters which rely on three separate displays as the splitters direct each color to one of the displays and three color displays are then re-combined. This method has a disadvantage of resulting in a noncompact display device.

U.S. Patent No. 4,277,138 discloses an optical device for creating spatially separate images of an object to be imaged. Each of the spatially separate images includes a specific spectral region, such as red, green and

blue. This patent utilizes a single lens for establishing the three separate images.

An alternative to these common methods is to use a diffraction grating with a lens array such that the light is split into its primary colors and directed into pixelated cells of the display. Although this concept has been suggested in the past by van Raalte in U.S. Patent No. 4,798,448, the design and the fabrication of the diffraction grating and lens array was not disclosed as it is difficult to fabricate a diffraction grating or lens array appropriate to separate a visible light spectrum.

Summary of the Invention

The present invention provides an apparatus and a method for dispersing a visible light spectrum into primary color bands and directing each color band into a corresponding pixelated cell of a passive display screen. The invention includes a diffraction grating and an array of refractive microlenses such that the diffraction grating separates the visible light into its primary color bands and the microlenses focus the separated bands into corresponding cells. In one aspect of the invention, the diffraction grating has an echelle structure which separates color bands into different diffraction orders. In another aspect of the invention, the diffraction grating has a blazed structure such that all color bands are diffracted into one order but the dispersion of the grating separates the bands within that order. In another embodiment the grating is a linear grating utilizing the +2, 0, and -3 orders. The diffraction grating may separate the light in one or two dimensions.

Brief Description of the Drawing

In the drawing:

Fig. 1 is a profile view of a blazed grating and its diffraction efficiency curves for the +1 order, the 0 order and the -1 order.

Fig. 2 is a profile view of a blazed grating illustrating separation angles and horizontal offsets for light passing through the grating.

Fig. 3 is a profile view of an echelle grating and its diffraction efficiency curves for the +1 order, the 0 order and the -1 order.

Fig. 4 is a profile view of an echelle grating illustrating separation angles and horizontal offsets for light passing through the grating.

Fig. 5 is a schematic diagram of a passive display device with an array of microlenses and a diffraction grating according to the present invention.

Fig. 6 is a graphical representation of the thickness profile of a linear diffraction grating for use in the present invention showing optical path difference (OPD) as a function of a normalized x-coordinate (x divided by the period T).

Fig. 7 is a graph of the diffraction efficiency curves for the grating profile of Fig. 6.

Fig. 8 is a schematic illustration of an echelle grating effecting a one-dimensional color separation.

Fig. 9 is a schematic illustration of a diffraction grating for effecting a two-dimensional color separation.

Fig. 10 is a schematic illustration of a grating design for two-dimensional color separation.

Fig. 11 is a graph of diffraction efficiency curves for the grating profile of Fig. 10.

Description of the Preferred Embodiment

Before presenting the specifics of the present invention, the theory behind diffraction gratings for separation of a light spectrum will be discussed.

A linear grating **10** may be approximated by a staircase profile as shown in Fig. 1. Each step **12** has a physical depth of

$$d = \frac{\lambda_0}{[N(n_0-1)]}, \quad (1)$$

where N is the number of steps per grating period **14** and n_0 is the index of refraction of the material at the design wavelength λ_0. Each step introduces a $2\pi/N$ phase shift for a total phase shift of 2π across one grating period **14**. The diffraction efficiency curves (λ vs η) for the 0 order **18**, the +1 order **16** and the -1 order **20** in Figure 1 show that at λ_0, the grating is blazed for the -1 order. The diffraction efficiency for an i th order of an N-step linear grating is

$$\eta(i,\lambda) = sinc^2\left(\frac{i}{N}\right) sinm^2\left[\frac{\lambda_0}{N\lambda} + \frac{i}{N}, N\right], \quad (2)$$

where

$$sinc(x) = \frac{\sin(\pi x)}{\pi x}$$

and

$$sinm(x,N) = \frac{\sin(N\pi x)}{N\sin(\pi x)}.$$

In a linear grating, all wavelengths are diffracted primarily into one order. However, the dispersion of the grating separates the wavelengths **22**, **24** within that order as illustrated in Fig. 2. Light of wavelength λ is diffracted at an angle

$$\sin\theta = \frac{i\lambda}{T} \quad (3)$$

where i is the diffraction order, λ is the wavelength and T is the grating period **14**. Therefore, a linear grating laterally offsets all wavelengths including the design wavelength **22** by

$$x = \tan\theta\ z, \qquad (4)$$

where z is the distance to the plane of interest **28** and θ is the angle of diffraction **30, 31**. The design wavelength λ_0 is offset by amount x_0 **23** and a shorter wavelength λ_{-1} **24** is offset by amount $x_0 - \Delta x$ **25**.

An echelle grating **32** is shown in Figure 3. This element also consists of N steps **33** per period, but each step **24** has a physical depth of

$$d = \frac{\lambda_0}{(n_0-1)}, \qquad (5)$$

such that each step is N times deeper than a linear grating step. Each echelle step introduces a phase shift of 2π at the design wavelength of λ_0. As shown in the diffraction efficiency graphs for the 0 order **38**, the +1 order **36** and the -1 order **40** in Fig. 3, at λ_0, the structure **32** behaves like a flat plate and is most efficient in the 0 order **38**. However, at the wavelength λ_{-1}, which is equal to $\lambda_0 N/(N+1)$, each step introduces a phase shift of $2\pi\lambda_0/\lambda_{-1}$ which is equivalent to $2\pi/N$. Therefore, it is effectively blazed for the -1 order **40**. Likewise, λ_{+1} is effectively blazed for the +1 order **36**. The diffraction efficiency peak of an i th order occurs at the wavelength

$$\lambda = \frac{N\lambda_0}{mN-i}, \qquad (6)$$

where m is an integer, N is the number of steps per profile and λ_0 is the design wavelength. The diffraction angle of each diffraction order **42, 44** and the lateral offset **46, 48** shown in Fig. 4 can be calculated from equations 3 and 4. The design wavelength **44** in the echelle structure is always undiffracted, thus it is never laterally offset; while the shorter wavelength λ_{-1} **42** is offset by amount ΔX.

The present invention is schematically illustrated in Fig. 5. This embodiment includes an array of refractive microlenses **50** and a diffraction grating **52** arranged parallel and in close proximity to the plane of the lenses

50. This combined device is arranged between a light source **54** and the passive display **56**, such that the microlenses focus the light coming from the source **54** onto the liquid crystal display and the diffraction grating separates the light into primary colors. The result is that each primary color is directed into a corresponding liquid crystal cell **58** within a pixel **60**.

In one embodiment, the diffraction grating **52** has an echelle structure as illustrated in Fig. 3. The echelle structure diffracts a light spectrum into its primary colors red, green and blue, such that green light is diffracted into the zero order, while red light and blue light are diffracted into the +1 and the -1 orders respectively. As the green light is undiffracted, it is not laterally offset. The red light and the blue light, on the other hand, are diffracted into opposite orders and therefore one is offset to one direction and the other is offset to the opposite direction. The refractive lenses **50** arranged near the grating **52** focus the light onto the display such that all the light would focus at the same location in a pixel, but the grating laterally offsets one color's focal point from another. The refractive lenses **50** and the grating **52** may be fabricated onto the same substrate, may be combined into one device or may be separate devices placed close to one another.

A 4-step echelle grating with a period of 16 μm has been fabricated for a design wavelength of .525μm using binary optics technology. See, U.S. Patent No. 4,895,790 for a discussion of this fabrication technology. The optical design of the echelle grating was transformed into a set of photomasks. To produce the final 16μm period echelle, two Cr-photomasks with 50% duty cycle gratings of periods 8μm and 16μm were used. The pattern was then etched onto a substrate surface. A 2" diameter, 6 mm thick Suprasil fused silica disks with index of refraction of 1.46 was polished on both sides to a top surface flatness of $\lambda/10$ to serve as the substrate. The mask with the smaller features was printed and etched first in a Perkin Elmer sputter-etch system to a target depth of 1.14μm. Afterwards, the second mask was printed and etched to a target depth of 2.28μm. The

depth of a single step was 1.14μm and the total depth of the echelle was 3.42μm.

Although this embodiment was fabricated with silica, it is to be understood that the invention may be fabricated with any material that is appropriate for use in the visible spectrum.

In another embodiment, the diffraction grating is a blazed grating as illustrated in Fig. 1. In a blazed grating, all of the visible spectrum is diffracted into one diffraction order, but dispersion caused by the grating separates the wavelengths within that order such that shorter wavelength light will be diffracted at a smaller angle than longer wavelength light. In this manner, red light, green light, and blue light may be separated. As in the previous embodiment, an array of microlenses **50** along with a diffraction grating **52** focuses the separated light onto an array of liquid crystal cells **56**. As the focal point of each color band can be determined, a cell corresponding to a particular color may be placed appropriately to receive that color. This embodiment is called off-axis microlenses as it looks and behaves similarly to decentered diffractive lenses known as off-axis lenses. The difference, however, is that the off-axis lens of the diffractive version shifts the focal points of the separated light longitudinally, whereas an off-axis lens of the refractive version shifts focal points laterally. This distinction results because focal lengths vary with wavelengths in a diffractive lens but not in a refractive lens. The only light separating component in a refractive off-axis lens is a grating which disperses light.

In this embodiment, the refractive lenses and the grating may be fabricated on the same substrate, may be combined into a single device or may be separate devices positioned near each other.

A single device combining a refractive lens with a blazed grating has been fabricated to separate infrared light into 8 μm, 10μm and 12 μm bands as presented in *Optics Letters* Vol 18, No 15. Silicon off-axis microlenses with F/2 microlenses, focal length of f=200 μm and a pixel size of 100 μm

x 100 μm may be fabricated for infrared light to be separated into 3 color bands. The lens is corrected for spherical aberration and has a thickness profile given by

$$t_L(x,y) = t_{L0} + \frac{(b+\sqrt{b^2-4ac})}{(2a)}, \quad (7)$$

where $t_{L0} = 5.2\ \mu$m is the maximum thickness of the lens, $a = n^2 - 1$, $b = 2nf - 2n^2f$, $c = n^2(x^2 + y^2)$ and $n = 3.42$. In order to separate the "red" light and the "blue" light focal points laterally by 50 μm, a grating of period 16.7 μm (6 grating periods per pixel) is used. The grating is blazed for the "green" light, so the thickness profile of this linear grating is

$$t(x,y) = t_{G0}(x \bmod T)/T, \quad (9)$$

where t_{G0} 1 is 4.1 μm, the grating period is $T = 16.7\ \mu$m , and mod ( ) refers to the modulo operator. The profile of the off-axis microlenses is obtained from simply combining the thickness profiles of the refractive lenses and the linear grating.

To obtain the refractive lens/diffractive grating combination, the thickness profile is converted into a set of four photolithographic masks. A silicon substrate is coated with a positive photoresist, patterned by contact photolithography and etched in a commercial parallel plate reactive-ion etching system for the first lithographic step. For the later steps, a multi-layer resist is required due to existing deep topography. First, a thick layer of high-viscosity AZ P4000 series photoresist is used to planarize the existing topography. Second, a layer of SiO_x film is deposited by electron-beam evaporation to function as the intermediate transfer layer. Finally, a layer of positive photoresist is used as the imaging layer. The SiO_x film is patterned by RIE in a CHF_3 plasma, and this pattern is duplicated into the planarization layer by O_2 RIE. The subsequent Si etching process is unchanged.

The target etch depths for this device are 0.52, 1.03, 2.07, and 4.13, resulting in a cumulative etch depth of 8 μm.

Although this embodiment has been described for silicon and the infrared region, a similar device may be fabricated to separate visible light. As a typical example, silica off-axis lenses might consist of F/2 microlenses with a focal length of f=40 μm and a pixel size of 20 μm x 20 μm in combination with a grating of period T=1 μm.

Fig. 6 illustrates a grating thickness profile which is neither an echelle grating as illustrated in Fig. 3, nor a blazed grating shown in Fig. 1. As shown in Fig. 7, the grating of Fig. 6 diffracts light into a -3 order **70**, a 0 order **72** and the +2 order **74**. In particular, red light is diffracted primarily into the +2 order **74**, green light into the 0 order **72** and blue light into the -3 order **70**. The grating of Fig. 6 has some advantages over the echelle grating illustrated in Fig. 3. In an echelle grating, the red and blue colors are diffracted into complementary orders (+1 and -1), but they are not diffracted into complementary angles (the red light will be diffracted upwards by an angle greater than that with which the blue is diffracted). In the grating of Fig. 6, the red and blue light are diffracted into complementary angles (equal upwards and downwards angular diffraction) although they are not in complementary orders (+2 and -3).

As shown in Fig. 8, the echelle grating **32** (also shown in Fig. 3) diffracts light in a one-dimensional fashion as illustrated in the right hand portion of Fig. 8. By contrast, a diffraction grating **90** (Fig. 9) diffracts light in a two-dimensional fashion. That is, as shown in the right hand portion of Fig. 9, blue and green light are diffracted in a single plane while the red light is diffracted out of the plane. The advantage of the design in Fig. 9 is that some color displays have red, green and blue pixels which are not linearly arranged but which are arranged in a two-dimensional pattern.

Fig. 10 illustrates a grating thickness profile which diffracts light in a two dimensional manner as depicted in Fig. 9. The bold rectangle 91 in

Fig. 10 shows the basic grating period. The grating is divided into rectangular areas which are of constant height and the height of each area is given by the number shown (e.g., 0.25 λ means that area should be of a height to introduce an optical path difference of 0.25 waves at the design wavelength usually in the green part of the spectrum). Note that although this design is shown to be composed of rectangular areas of constant height, neither the rectangularly shaped areas nor the constant height of each area is a requirement for this embodiment. Fig. 11 is a graph of the defraction efficiency curves for the grating profile of Fig. 10. The diffraction orders now have two indices since the design is two-dimensional in nature. In particular, as shown in Fig. 11, the grating of Fig. 10 diffracts blue light into the (1,1) order 92, green light into the (0,-1) order 94, and red light into the (-1,1) order 96.

It is recognized that modifications and variations of the present invention may occur to those skilled in the art, and it is intended that all such modifications and variations be included within the scope of the appended claims.

What is claimed is:

1. Optical apparatus for dispersing a visible light spectrum into primary color bands and directing each color band into a specific pixelated cell of a passive display comprising:

an array of refractive microlenses arranged parallel to the plane of the display and

a diffraction grating arranged parallel and in close proximity to the lens array,

wherein said microlenses focus the visible light onto the display, while said diffraction grating separates the visible light into primary color bands in different diffraction orders, such that said colors are directed to and transmitted through the corresponding specific pixelated cells.

2. The apparatus of claim 1 wherein said array of microlenses is a one-dimensional array of microlenses.

3. The apparatus of claim 1 wherein said array of microlenses is a two-dimensional array of microlenses.

4. The apparatus of claim 1 wherein said diffraction grating is fabricated on the same substrate as the microlenses.

5. The apparatus of claim 1 wherein said diffraction grating has an echelle structure comprising a repeated profile of steps where all steps ascend in the same direction and each profile resets to the ground level after ascending to the top step of the profile.

6. The apparatus of claim 5 wherein each step of said echelle structure has a physical depth of

$$d = \frac{\lambda}{(n-1)}$$

where λ is the design wavelength and n is index of the material.

7. The apparatus of claim 5 wherein diffraction efficiency for a given wavelength in a particular diffraction order for said echelle structure is

$$\eta(i,\lambda) = sinc^2\left(\frac{i}{N}\right) sinm^2\left(\frac{\lambda_0}{N\lambda} + \frac{i}{N}, N\right)$$

where N is the number of steps per profile, i is the diffraction order, λ is the given wavelength and λ_0 is the design wavelength.

8. The apparatus of claim 5 wherein the number of steps in a profile determines the peak wavelength of a diffraction order as

$$\lambda = \frac{N\lambda_0}{(mN-i)}$$

where N is the number of steps per profile, λ_0 is the design wavelength, i is the diffraction order and m is an integer.

9. The apparatus of claim 5 wherein the width of said echelle structure determines the angle of diffraction for a wavelength diffracted in a particular order as

$$\sin\theta = \frac{i\lambda}{T}$$

where λ is the wavelength, i is the diffraction order and T is the period.

10. The apparatus of claim 5 wherein said diffraction grating diffracts light into +1, 0 and -1 order, where each order corresponds to a particular wavelength.

11. The apparatus of claim 1 wherein, said primary colors are red, green and blue.

12. The apparatus of claim 10 wherein, green light is diffracted into 0 order while red light and blue light are diffracted into +1 and -1 order, depending on the direction of the ascending steps.

13. The apparatus of claim 5 wherein each profile has 4 steps.

14. The apparatus of claim 5 wherein each step has a depth of 1.14μm.

15. The apparatus of claim 5 wherein each period is 16μm.

16. The apparatus of claim 1 wherein said passive display is a liquid crystal display.

17. A method for dispersing visible light spectrum into primary color bands and directing each color band into a specific pixelated cell of a passive display such that each color is transmitted by the corresponding cell comprising:

focusing the light onto the display with an array of microlenses arranged parallel to the plane of the display and

separating the light into primary colors with a diffraction grating arranged parallel and in close proximity to the plane of the lens array.

18. An optical apparatus for dispersing a visible light spectrum into primary color bands and directing each color band into a specific pixelated cell of a passive display with an array of off-axis microlenses comprising:

an array of refractive microlenses arranged parallel to the plane of the display, and

a blazed diffraction grating arranged parallel and in close proximity to the plane of the lens array, wherein said microlenses focus the visible light onto the display while said diffraction grating separates the light into primary color bands within a single diffraction order such that each light is transmitted by the corresponding cell.

19. The apparatus of claim 18 wherein said diffraction grating and an array of refractive microlenses are fabricated on the same substrate.

20. The apparatus of clam 18 wherein said passive display is a liquid crystal display.

21. The apparatus of claim 18 wherein a blazing of the linear grating is approximated by a staircase profile with N steps per profile.

22. The apparatus of claim 21 wherein each step has a physical depth of

$$d = \frac{\lambda_0}{[N(n_0-1)]}$$

where λ_0 is the design wavelength, N is the number of steps per profile and n_0 is index of the material.

23. The apparatus of claim 21 wherein each step introduces a $2\pi/N$ phase shift for a total phase shift of 2π across one grating period.

24. The apparatus of claim 18 wherein the grating is blazed for one order at the design wavelength and all wavelengths are diffracted primarily into said order.

25. The apparatus of claim 18 wherein the dispersion of the grating separates the wavelengths within said order at the angle

$$\sin\theta = \frac{i\lambda}{T}$$

where i is the diffraction order, λ is the wavelength and T is the period of the grating.

26. The apparatus of claim 18 wherein the grating offsets the central wavelength by

$$\frac{x_0}{z} = \tan\theta_0$$

where x_0 is the amount of offset, z is the distance from the grating to the focal plane, and θ_0 is the angle of diffraction.

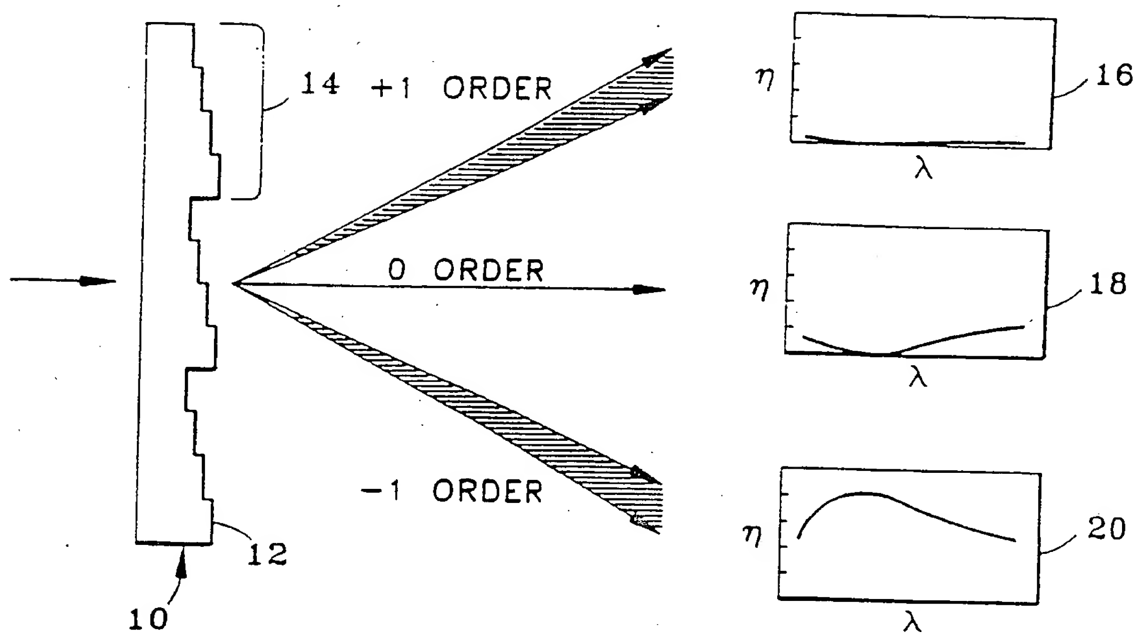
27. The apparatus of claim 1 or claim 18 wherein said diffraction grating and microlenses are combined into a single optical element.

28. The optical apparatus of claim 18 wherein said array of microlenses is a one-dimensional array of microlenses.

29. The optical apparatus of claim 18 wherein said array of microlenses is a two-dimensional array of microlenses.

30. The apparatus of claim 1 wherein red light and blue light are diffracted through opposite but substantially equal angles and green light is diffracted into the 0 order.

31. The optical apparatus of claim 1 wherein the diffraction grating is adapted to separate the visible light two-dimensionally.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12
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18
20

FIG. 1

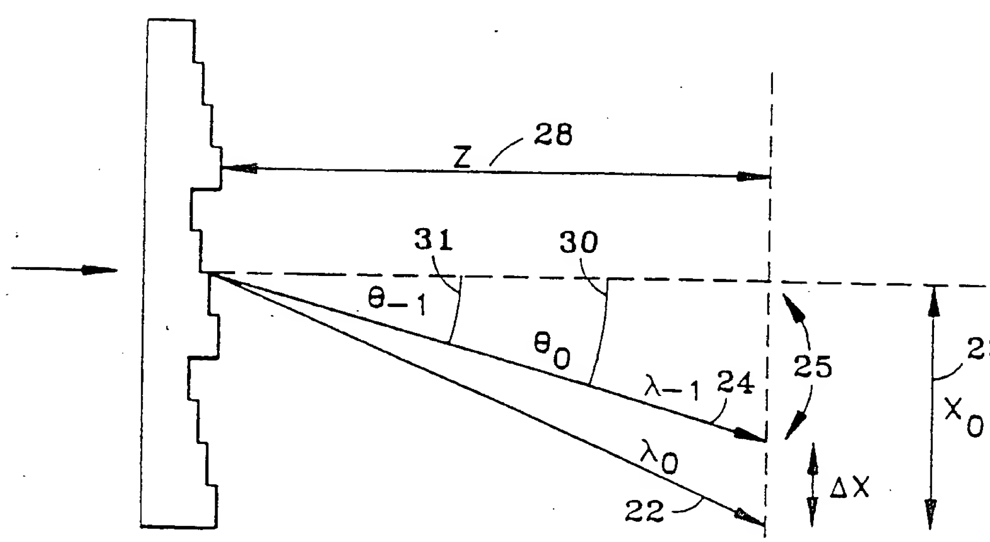
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FIG. 2

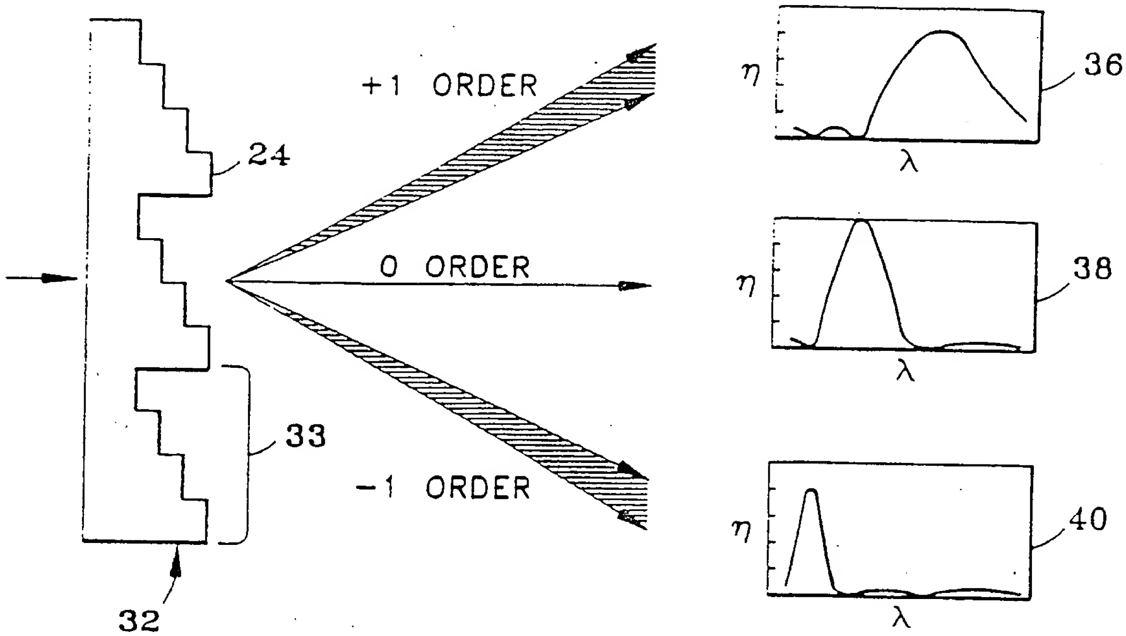

FIG. 3

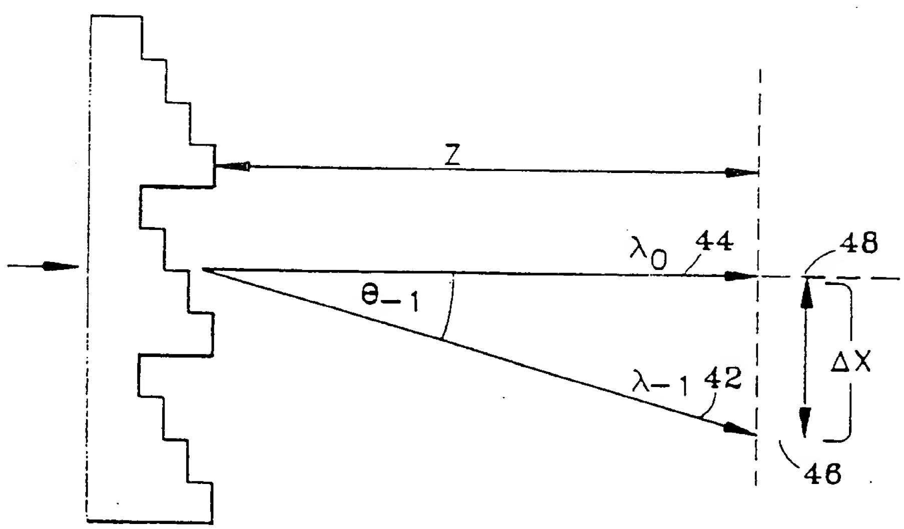

FIG. 4

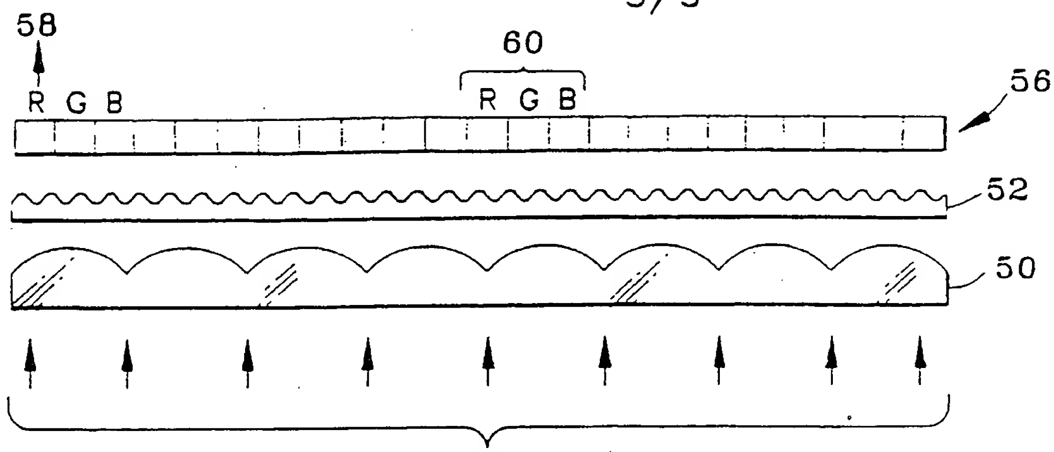

FIG. 5

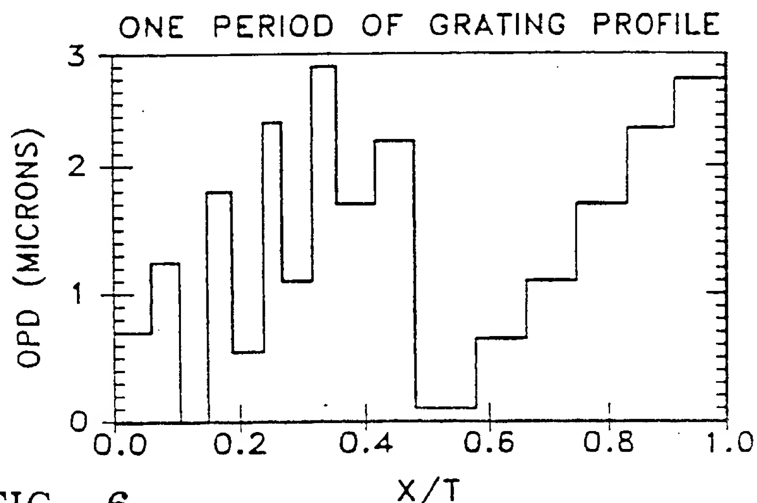

FIG. 6

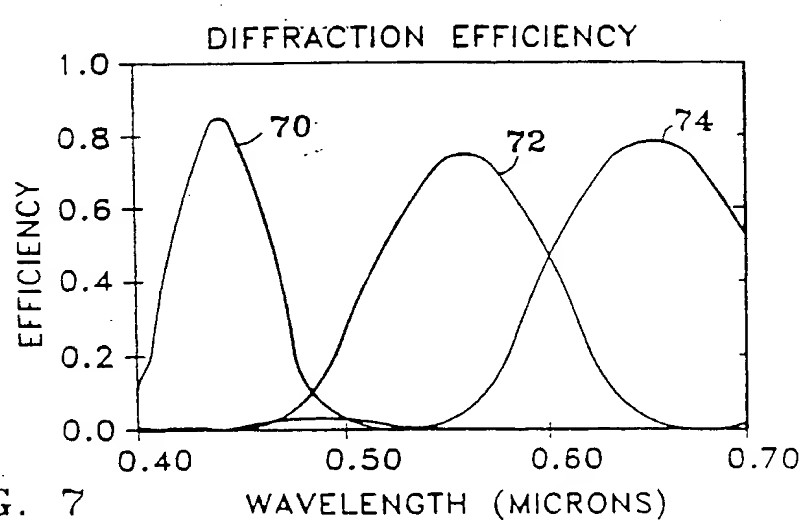

FIG. 7

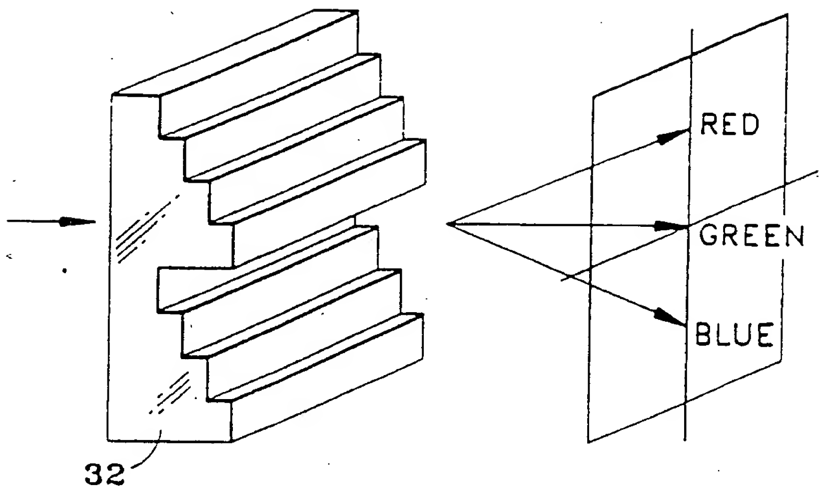

FIG. 8

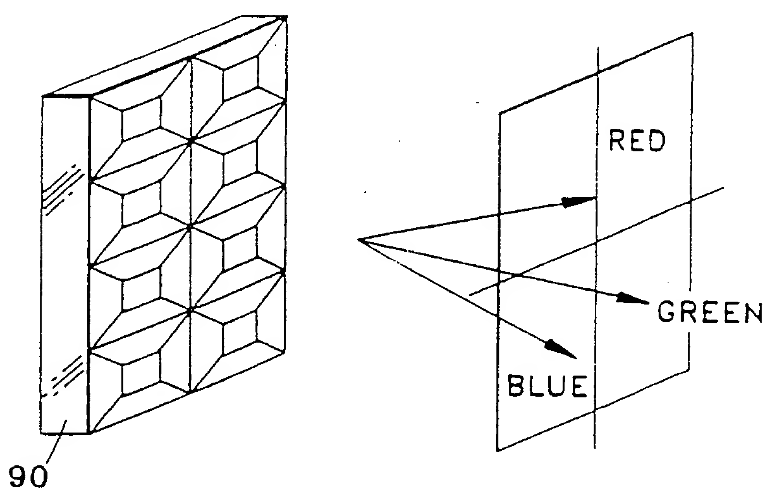

FIG. 9

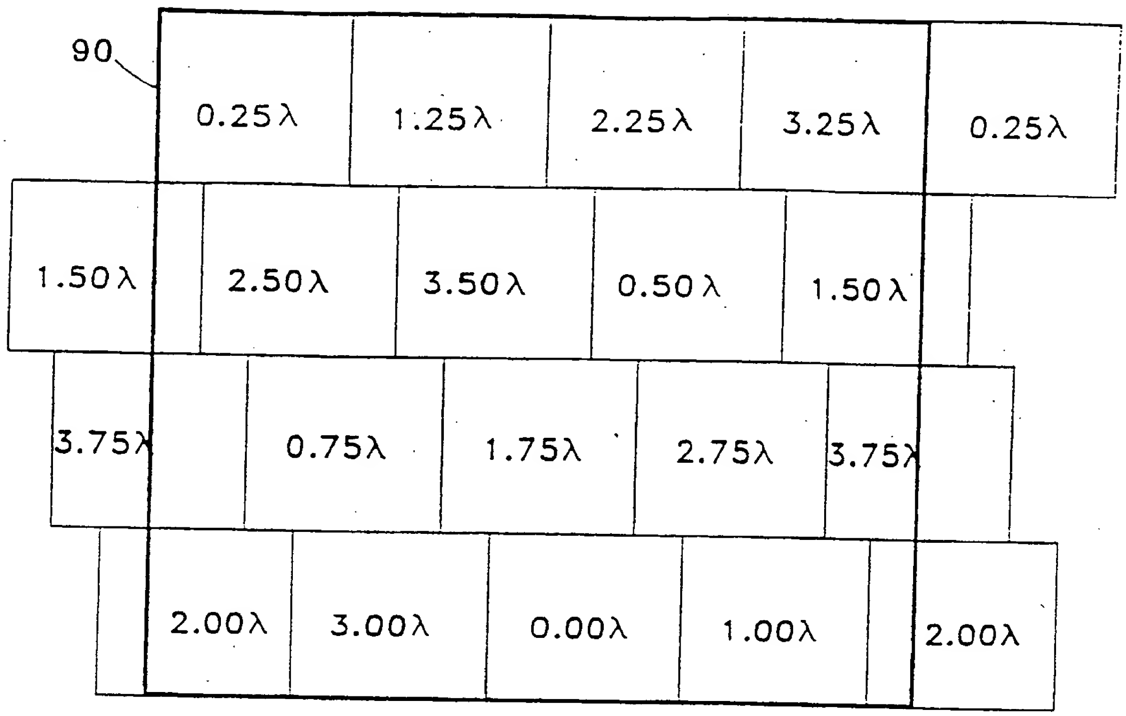
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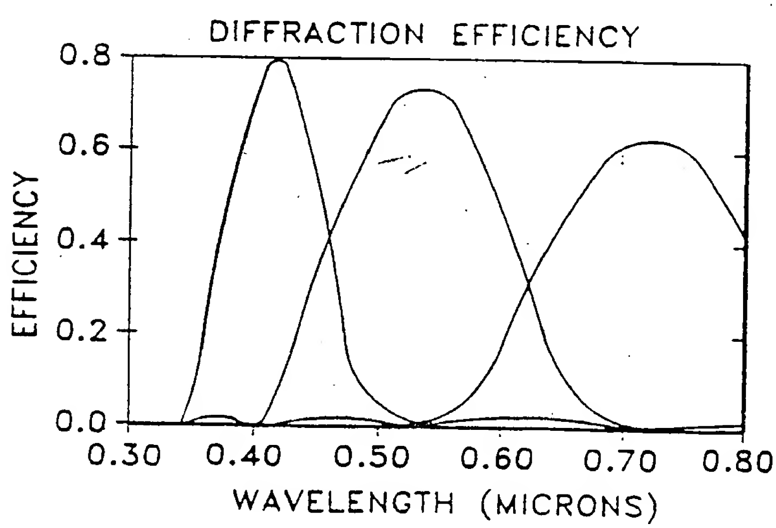
FIG. 10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WAVELENGTH (MICRONS)

FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/02141

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B5/18 G02F1/1335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 583 150 (SHARP) 16 February 1994	1,2,11, 16-18, 20,24,28
A	see the whole document	25,30,31
X	US,A,4 798 448 (VAN RAALTE) 17 January 1989 cited in the application	1,2,11, 16,17,30
A	see the whole document cited in the application	18,20, 25,28,31
X	PATENT ABSTRACTS OF JAPAN vol. 12, no. 185 (P-710) 31 May 1988 & JP,A,62 293 222 (CANON) 19 December 1987	1,2,4, 11,16,17
A	see abstract; figures	10, 18-20, 27,28,30

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
23 May 1995	- 2.06.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ward, S

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 12, no. 185 (P-710) 31 May 1988 & JP,A,62 293 223 (CANON) 19 December 1987	1,2,4, 11,16,17
A	see abstract; figures	10, 18-20, 27,28,30

X	IBM TECHNICAL DISCLOSURE BULLETIN., vol.36, no.9B, September 1993, NEW YORK US pages 453 - 456 'Improved Liquid Crystal Display Panel Illumination'	1,11,16, 17
A	see page 455, paragraph 1; figure 4	4,18-20, 30

A	OPTICS LETTERS, vol.18, no.15, 1 August 1993, WASHINGTON US pages 1214 - 1216 FARN ET AL 'Color Separation by use of Binary Optics' see the whole document	1,3,4, 11, 17-19, 24,27,31

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/US 95/02141

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0583150	16-02-94	GB-A- 2269697	16-02-94
		JP-A- 6230384	19-08-94
US-A-4798448	17-01-89	NONE	